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Revenue Management Systems, Inc.

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# What is Revenue Management?

Revenue Management first received serious attention in the airline industry. Starting in the early '80's, Revenue Management became a critical tool for business success. Today, Revenue Management is a widely accepted discipline that is providing increased revenue and profitability in the airline, hospitality, car rental, cruise line, railroad, and television broadcast industries.

The Wall Street Journal has identified Revenue Management as the number one emerging business strategy. It calls Revenue Management "a practice poised to explode". As a user of RMS' Revenue Management systems, your organization can expect to generate anywhere from 3% to 8% additional revenue, resulting in potential profit increases of 50%-100%.

Of course, none of this really explains what Revenue Management is. What is Revenue Management and how does it apply to my organization? As Aeronomics states, "Revenue Managment is the application of disciplined tactics that predict consumer behavior at the micromarket level and optimize product availability and price to maximize revenue growth. Revenue Management is about maximizing revenue from existing business. It's a hard management science that employs rocket-science mathematical concepts and high-powered computers to crunch gigabytes of marketing information to:

- Accurately assess future consumer behavior under dynamically changing market conditions
- Determine the most effective way to price and allocate inventory to reach and every future consumer, each and every day, making real-time adjustments as market conditions change, with the consumer in real-time
- Communicate this information instantaneously to distribution and sale outlets which deal with the consumer in real-time
- Serve as a decision-support resource for marketing and operational functions, including but not limited to: pricing, scheduling, product development, advertising, sales, distribution, human resource utilization and capacity planning."

Revenue Management Systems, Inc. offers Revenue Management software for the airline industry. When Revenue Management was first applied in the airline industry, it was applied manually. However, the enourmous scope of the problem (managing tens of thousands of flight departures departing over the next year) convinced the early adopters of this practice that only through computerization could the airline capture the revenue opportunity that Revenue Management provided.

# The Need for Computerized Revenue Management

Today, most airline managers understand that they are not maximizing the revenue potential from each and every flight departure. They are under- utilizing their most valuable asset – their perishable seat inventory. In an attempt to maximize their seat inventory, most airlines implement some type of revenue management methodology. Some airlines set global authorization levels for certain flights in certain markets. Others

assign analysts to examine the status of future flights, usually through a reservation terminal, in an attempt to juggle the mix of full fare and discount availability. Still others have implemented simple spreadsheet approaches to analyzing flight performance. Each of these solutions captures additional revenue that would otherwise be lost.

But in fact none of these solutions allow the airline to capture the spilled revenue that is left lying at the gate as the aircraft pulls away. This is because a number of factors limit their ability to deliver the optimal solution. First, the sheer number of flight departures that require attention daily is overwhelming. Second, individual flights experience enough variation to make it impossible to assume that what took place last week will probably happen again this week. Third, for many airlines, understanding each fare's relative value and managing the relationship between them makes determining the best mix of fares difficult.

The result of these approaches are aircraft filled with discount passengers, obtaining a low yield and less than optimal potential revenue, or aircraft partially filled with high-paying passengers, obtaining a low load factor, high yield, but, again, less than optimal potential revenue. To succeed in this highly competitive industry, airlines need a computerized revenue management system in order to fill each aircraft with the mix of seats that results in the capture of the maximum revenue.

# *The Benefits of Computerized Revenue Management*

The ultimate benefit of computerized revenue management is increased revenue. Each flight departure is managed to insure that it generates the maximum possible revenue from the ideal mix of both high and low yield passengers. You can expect this system to generate anywhere from 3% to 8% additional revenue for your airline, resulting in potential profit increases of 50%-100%. Of course, your level of improvement depends upon how revenue management was utilized at your airline prior to the implementation of the computerized system.

In addition to increased revenue, computerized revenue management systems provide a number of other benefits. For example, through the effective implementation of overbooking controls, goals can be set for denied boardings rates rather than accepting denied boardings as an unavoidable and uncontrollable cost. Overbooking systems set aircraft overbooking levels which minimize the combined cost of empty seats, voluntary denied boardings, and involuntary denied boardings.. For many airlines, this will be the first time that they are able to proactively use denied boardings as a tool to generate revenue.

New analysts can become effective more rapidly when they have a reference tool that helps them understand the relationship between historical and future behavior. Without such a tool, the analyst only learns about the flight's behavior through extensive experience.

At the same time, management benefits from an effective revenue management system. Management gains a decision-support resource for marketing and operational functions. Having at their disposal a tool that can analyze historical and forecast future behavior is invaluable when planning marketing campaigns, and pricing and schedule changes.

The analysts gain a tool that helps them focus their attention where it is needed, when it is needed. A tool that can provide them the confidence to make the right decision while enabling them to apply their own knowledge and abilities to the maximum benefit.

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# Revenue Management: Winning in the 21st Century

**40th NABE Annual Meeting**
**Washington, D.C.**
**October 4, 1998**

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## Revenue Management

In the most recent issue of NABE News, several prominent business economists were asked to comment on the state of the profession. Maureen Haver, NABE President in 1994-95 said that, "CEOs now want business economists to focus on the companies themselves ... to become more micro-oriented." Lawrence Small, President and COO of Fannie Mae opined that "business economists who get out of the ivory tower and into the trenches of the marketplace can have a bright future in the corporate world of the next century, while those that don't, are an endangered species. The future is to get as close as possible to the areas that create revenue for a company and find ways to make oneself relevant to those areas."

Revenue Management is a discipline that combines statistical techniques of forecasting with the numerical optimization techniques that have their origins in Operations Research; but is based squarely on the consumer and firm behavior models that are the stuff of micro-economics. The discipline had its origins in the newly de-regulated world of the airline industry of the early 1980's and has since found its way into all sectors of the travel industry, as well as freight, media, utilities and retail trade. It has been credited with billions of dollars of increased revenue and earnings over the last decade and a half. Its early successes coupled with dramatic advances in computational power will inevitably drive this discipline more deeply into industries where it is already mature and more broadly into new industries and markets.

## A Revenue Management Modeling Framework

At its heart, RM comprises a set of models of business decisions. These decisions govern what products a firm sells, to whom the products are sold and how the firm combines its resources to deliver its products. While these optimization decisions are well described in any microeconomic theory or managerial economics textbook, the discipline of RM provides a framework and a set of techniques, results and problems that guide the practical, numerical implementation of the standard theoretical results.

A compact, yet rich framework in which to think about and organize RM models, is Object Oriented Analysis (OOA), devised by Grady Booch and others to facilitate business software design, development and evolution. The basic

elements are objects, which correspond to entities in the real world. These objects are the nouns of the language of RM. The objects have behaviors that may be either internal to themselves or that are reactions to stimuli from other objects. These behaviors are the verbs. Finally, there are domains that reflect the scope of the model and the institutional structure in which the objects interact.

### *Objects or Nouns*

Objects are the building blocks of models. For RM models, there are five types of objects: resources, products, customers, competitors and the firm itself.

#### Resources

Resources are the (predominately physical) assets which are available to the firm and which may be transformed into products that have value to customers. In the airline industry, these are seats on a flight leg; in the hotel industry these are rooms on a given night; in the outdoor industry, these are billboards in a location on a day.

Resources are the "things" that the firm delivers, or commits to deliver, to the customer. However, the resources themselves rarely provide value directly to the customer.

The characteristics of resources that we are most interested in are their availability and their cost.

#### Products

Products are the commitments that the firm makes to deliver bundles of resources to customers. It is these commitments that customers value and are willing to pay for. While some products may "bundle" a single unit of resource, most products comprise multiple units.

In the airline industry, a product may be a promise to transport the customer from Miami to Los Angeles in no more than seven hours, arriving before dinnertime on Wednesday, October 8. It may be a provisional commitment, such as in airfreight where the product may be "delivery of 600 cubic feet of cargo to Jacksonville as soon as possible, but in any event within three days."

Characteristics of products that are relevant for RM modeling are the production relationships, the ways in which the firm can "assemble" the product from resources; and, in some cases, the distribution channels through which products may be made available to customers.

#### Customers

Customers are those that value the firm's products; and they may also value products offered by competitors in the market. In some cases, customers are modeled individually; for example, in the media industry a single customer may request commitment of a complex bundle of resources over an extended period of time. The firm may know a great deal about that customer's needs, alternatives and willingness to pay. In other cases, customers are dealt with in the aggregate, as customer types or as market segments. For example, many firms in the travel industry offer products at certain prices for "qualified" customers, such as AARP discounts.

The qualification provides one means to classify customers. Other means of classifying customers are by type of product demanded and distribution channel. This aggregation assists in developing estimates of the size of the class and its behavior. It is these characteristics of customers that are most relevant in RM modeling.

#### Competitors

Competitors are other firms whose actions may be relevant, in terms of the behavior of customers. The characteristic of a competitor that is most often reflected in RM models is the set of prices for, and the availability of, substitute products. In the case of an airline, the willingness of a customer to "buy up" when the own-airline's most desired product is not available, may be a function of the availability of like products offered by its competitor(s).

In addition to modeling competitors' somewhat static price and availability, some RM applications are beginning to explicitly incorporate a competitor's reaction to a price adjustment by the own firm.

#### Firm

The firm is the entity that is making choices in the furtherance of its objectives. The characteristics of the firm

relevant for RM modeling is the choice set available to the firm; its objective(s), and often, some policy constraints.

The choice set is often dictated by technology and industry standards. For example, airlines would like to discriminate between booking requests on a given flight, based on each passenger's entire itinerary. However, such discrimination is not fully supported in the systems that travel agents use to check availability and confirm reservations.

It is convenient to model the firm's objective as maximizing revenue or profit over some time horizon. However, in some cases, the firm's objectives include achieving a certain market share, or developing relationships that have consequences outside the scope of the model.

Finally, there may be policy constraints peculiar to the firm. For example, a broadcaster may require that no more than two fifteen-second commercials be placed in a single commercial break; or a cruise line may require that any price reductions be rebated to customers that have already purchased.

***Behaviors or Verbs***

The objects of RM modeling have many behaviors, which have varying degrees of relevance in different RM models. When included in the model, these behaviors are represented as mathematical expressions. These expressions may appear directly in the formulation of an optimization program, or may be equations used to forecast future behavior.

**Resources**

The primary behavior of a resource is its availability over time. This is a function of current commitments, expected future commitments, and the realization of uncertain or provisional commitments. So, in most RM models, availability of resources appears as a set of constraint equations on the quantity of product that can be delivered.

In some case, resource availability is influenced in important ways by random customer behavior. In rental car applications, for example, stochastic return times (and sometimes locations) interact with stochastic customer arrival times in very complex ways. This leads to more complex expressions for availability.

Finally, there are RM problems in which availability is within the choice set of the firm. In this case, resource availabilities may appear explicitly in the objective function that is to be optimized.

**Products**

Products are perhaps the most challenging of RM objects to model. This is because many products can be produced in a variety of different ways. In a media application, for example, the product is an audience, with certain demographic characteristics, over some set of calendar dates. That product may be provided by a very large set of alternative combinations of commercial spots. Or, when a customer purchases a coach class seat on an airline, there are a number of ways that the airline can deliver on that commitment: narrow- or wide-body airplane; aisle, middle or window seat; or an upgrade to first class.

Products are expressed as a set of definitions or equations that describe the allowable resource bundles. In RM models that optimize product price or availability, these choice variables and product definitions provide the linkage between the objective function value and the underlying resource constraints.

**Customers**

There are two dominant characteristics of customers in RM modeling. These are the quantity and the willingness-to-pay distributions of the customers; in other words, their demand function. Some applications use one or the other and some use both. The primary behavior of customers is the changes in the quantity of the firm's products that is demanded, over time and in response to the choices of the firm and actions of competitors.

A common issue in estimating the parameters of the demand function is that the firm often does not observe all possible customers, due to capacity constraints or price decisions that truncate the demand. This is addressed by use of an unconstraining model, which allows the system to "see" all of the demand in the market, whether or not a particular customer or customer type has actually "registered" his or her demand with the firm's sales or distribution system.

Most RM decisions are concerned with demand that has yet to materialize, so forecasting models are required. These predict the quantity of customers that will demand each product, at each point in time between now and the

delivery date.

Willingness-to-pay is not directly observable, but is a crucial characteristic in many RM model applications. One way that this characteristic is expressed is as a buy-up propensity. This parameter is an estimate of the proportion of customers of a certain type that will pay for a higher priced product, if their most preferred product is unavailable. Another way that willingness-to-pay is modeled is as an explicit own-price elasticity, usually assuming either a linear demand or a constant elasticity functional form.

These customer behaviors are uncertain. There is uncertainty with respect to what a particular customer will do when the firm declares its price decision; there is uncertainty with respect to the quantity and characteristics of customers that will present their demand in the future. These uncertainties are often reflected in the RM models by treating quantity demanded as a random variable, drawn from distributions whose parameters are estimated from historical behavior.

**Competitors**

The most prevalent competitive behavior that is captured in RM models is the current price, and sometimes availability, of the competitor's relevant products. This is reflected in the expression of customers' willingness-to-pay for the own-firm's products. Reliably capturing these data is often difficult. Even in the airline industry, with its electronic distribution systems, it is quite hard to determine exhaustively what products are competitive to one's own, much less their availability at a point in time. The technology in this area is improving.

Another behavior of competitors is their reaction to the own-firm's actions. In a model to support airline pricing, an important input into the model is the speed with which competitors match the fare action. The slower the reaction, the greater the revenue impact, *ceteris paribus.* In other cases, the reaction is modeled as the expected magnitude of the response.

**Firm**

Firms make decisions. This decision-making is the behavior that is relevant in RM models. The decisions are choices amongst a set of alternatives that may be dictated by technology, policy, industry practice or regulation. In many cases, these are product availability or price. In other cases, they are the assignment of resources to specific customer commitments or to specific products. In still other cases, choices are the terms of an extended commitment to a single customer.

These choices are reflected in the structure of the objective function in the optimization model.

***Domain***

The domain of RM models is extensive in the dimensions of space and time. The market is the spatial model domain, and defines the actors in the RM model and the decisions that it will support. The actors are those objects that are instantiated in a specific model, and their permissible behavior. These, in turn, define the supported decisions through the allowed behavior of the firm actor.

The simply means that the market is the set of customers and competitors that are relevant for the specific model. In its simplest form, it may comprise only the customers, aggregated into market segments, which are modeled as mutually independent; and thus the model ignores competitors and any substitutability amongst the firm's products. In more elaborate cases, intra-firm substitution is modeled, along with response to endogenous competitor actions.

In some applications, decisions are atemporal and the time dimension is unimportant. Although airlines typically make availability decisions over a horizon of a year, decisions on one departure date have no important consequences for decisions on other departure dates. In other cases, intertemporal consequences are paramount. When a hotel makes a commitment to a single customer, or a group, that commitment directly affects resource availability over a range of dates. In this case, an important dimension of the optimization model is the horizon over which the problem is to be solved.

**Revenue Management Decisions or Problems**

There are many business decisions that are, or could be, fruitfully modeled and solved within this framework. Choices, based on data quality and model parsimony, dictate the degree to which all of the potential behavior of the objects is explicitly modeled in a particular case, however. For example, it is conventional in many applications to ignore the competitor's behavior; thus a "Competitor" object may be non-existent in the model. It is also often the

case that the model representation of the potential product space is limited. Even a modest-sized airline may have over 100,000 feasible itineraries, each operating every day for the next 360 days, with a twenty or more fare products on each; so an airline O&D RMS may only model the itineraries with significant demand, and then only for selected departure dates.

### *Allocating Resources to Products*

This is the most common and well-understood class of RM problems. The original impetus for finding solutions was in the airline industry, as it grappled with the two problems of no-shows and a multiplicity of fare products.

### Availability Controls

The most basic problem within this class is an airline's choice of how many seats to sell on a flight, given uncertainty in the show-up behavior of customers holding reservations. The solution approaches embody quantifying the tradeoff between the revenue lost when seats are empty, referred to as spoilage; and the costs incurred when more booked customers show up than there are physical seats, referred to as denied boarding costs. (See Figure 1.)

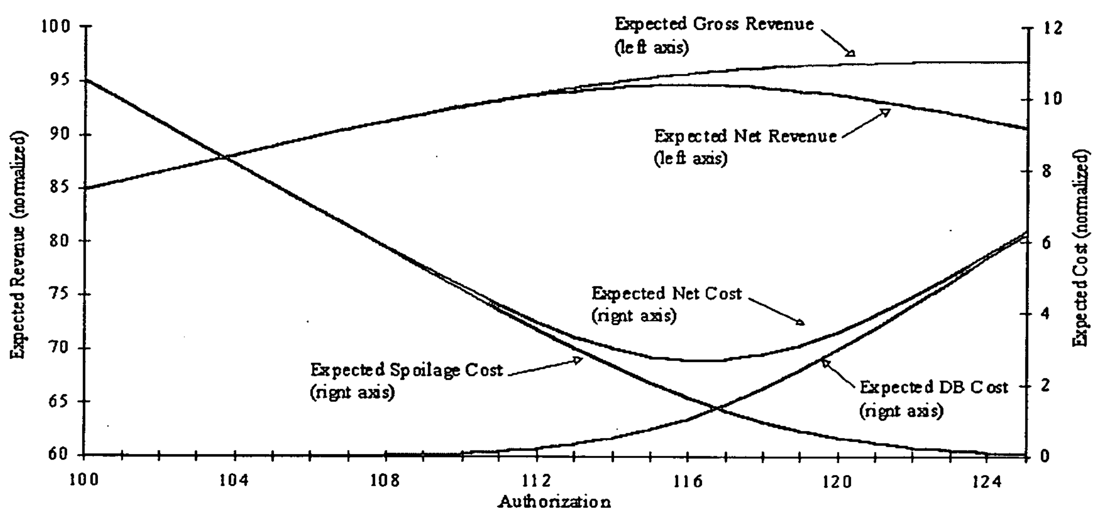


Figure 1

Another problem is how to allocate resources amongst a variety of product-customer combinations. If there is one seat available on the noon flight from Washington to Chicago on Oct 15, should we accept a discount fare booking for an itinerary originating in London? Or should we reserve the seat for a business customer who will pay full price? The answer will depend, *inter alia*, on the probability of the high fare business materializing; the probability of the high fare booking canceling after it is booked; the availability of seats on other flights from Washington to Chicago and on flights connecting from Chicago to the West Coast. We may even consider the estimated lifetime value of customers in the two segments.

These availability problems may be thought of as optimizing the use of resources within the market, over the model horizon. Instead of choosing an output level that equates marginal production cost to marginal revenue, the problem is to choose output levels of all possible products that can be produced with the production resources, so as to equate marginal revenue with marginal opportunity cost, or marginal value. If these optimality conditions are achieved, then the production plan, i.e., choice of products to be made available for sale, is optimized. (See Figure 2).

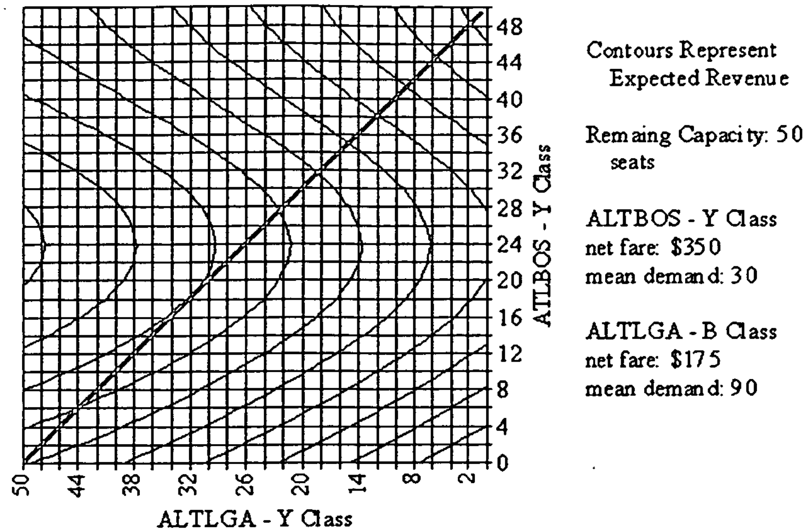


Figure 2

In these models, there is barely a shadow of competitors. However, in practice, most such systems re-forecast demand and re-solve the optimization problem frequently. This has the effect of allowing the model to respond to changes in customer behavior, responding to changes in competitors' product availability, without it being represented explicitly in the model.

American Airlines pioneered these techniques, beginning in 1983 and remains a leader. All major domestic airlines utilize these techniques on a large-scale and most of the major international carriers do as well. Furthermore, there are many analogs to these traditional problems in other travel industry businesses. Marriott Hotels and Resorts was the first major hotel firm to embrace these techniques, in 1989. Now, virtually all major U.S. hotel chains deploy these techniques in some form. The overbooking problem is quite similar and length-of-stay considerations are analogous to the network problems that airlines face.

**Assignment Controls**

Assignment control problems treat the choice of how to combine bundles of resources to deliver products to customers. An example of an assignment control model is referred to as Optimal Placement. The problem here is, given demand for product that is unusually complex in its requirements, that can therefore be delivered with many combinations of resources, what is the optimal combination and the minimum price that should be charged? This problem arises in the media industry, where the product is impressions or audience, of a given type or demographic, over some date range; and the resources are commercial spots, column inches, or billboard "faces". It also arises in the travel industry, particularly in hotels, that are faced with complex requirement to satisfy a group booking that may require sleeping rooms, meeting rooms and banquet halls.

The difference between the assignment control problem and the traditional production planning problem is that in the former, production costs are essentially negligible. The important costs are the opportunity costs associated with foregone production of alternative products. The optimality conditions require that the difference between the revenue received and the opportunity cost be maximized.

***Pricing Products***

This class of RM problems is well-known, but except in a few applications, the modeling approaches and solutions are less well established than in the case of availability controls. One reason that this is the case is that explicit pricing models require numerical parameters that are difficult to estimate, in theory and in practice, including the own-price and cross-price elasticities. (Interesting, it has been shown that, under some conditions, the optimal pricing and optimal availability controls are equivalent.)

**Unit Pricing**

Unit pricing models are most well developed in the rental car industry. At the time that product availability appears in

the electronic distribution channels, usually 90-120 days in the future, each product is assigned a price. Product characteristics, including rental location, car type, rental duration, one-way or local rental; anticipated demand; and market positioning and competitor pricing largely govern the initial prices. Once bookings begin to materialize, product demand forecasts are updated. Then an optimization model evaluates the demand relative to the available resources and determines what resources to allocate to what products and what prices to charge for products that are to be made available.

The allocation of resources is usually in two dimensions. One is determining the number of low car class customers that should be upgraded into higher-value car types. Another dimension is the number of cars to make available for rentals of different durations.

In concert with determining these allocations, the model determines the optimal price to charge for each product that is to be offered. The optimization considers expected price responsiveness of customers in different market segments, competitors current prices and market position. Optimality requires that the vector of prices is such that marginal revenue for each product-customer combination is equal to the marginal value of the resources that will be required to just meet the demand.

Hertz was the leader in the development of these tools, in 1989. In 1993, the deployment of such a system was credited with saving National Car Rental from liquidation. Similar tools are now used almost universally in the rental car industry.

**Relationship Pricing**

An example of relationship pricing is a model referred to as Target Pricing, developed in the small parcel industry. In this industry, a customer is provided with access to all of the firm's products, e.g., same day delivery, next morning delivery, 2-day air, etc., for a specified discount off of the list price, for a specified term. The Target Pricing model estimates the discount that maximizes the expected contribution from the offer. The model captures customers' response to the offer price, relative to the competitor's price; changes in the relative offer price compared to last year's price and the expected competitor response. In addition, to capture longer-term customer value, the optimal offers are computed for future years, and via discounting and backward induction, incorporated into the computation of the current year's optimal offer.

A mix of statistical analysis of historical offers, market research and expert judgement is used to initialize the parameters in the model. Once the model is in production, statistical analysis using logistic regression methods is used to update the parameter values. The optimal results generated by the model may be tempered by strategic, market-share objectives.

Unlike RM models used for more bulk-oriented freight carriers, the Target Pricing model does not treat resources directly; however, the cost function reflects the capacity conditions of resources in the network. But these marginal costs are not sensitive to the acceptance or rejection of the commitment under consideration at the time, since resources can be made available at a constant marginal cost over the relevant range of sales. Thus the optimization problem is not one of optimizing resource usage; it is one of maximizing expected profit, by choosing price and thus expected output. (See Figure 3).

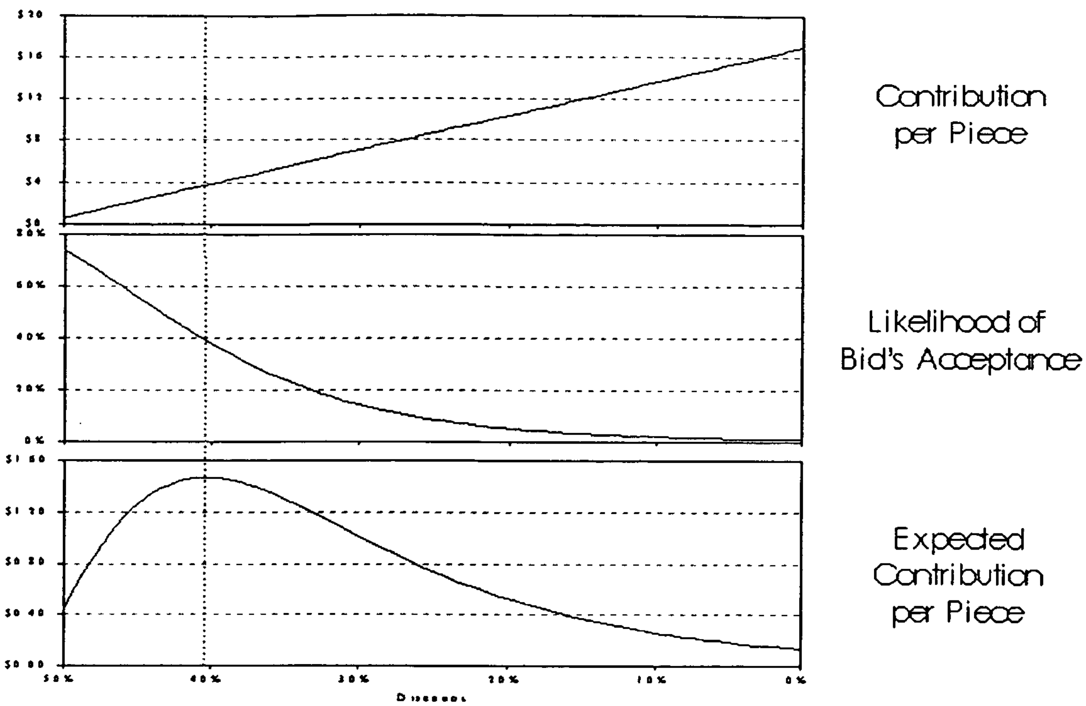


Figure 3

***Allocating Resources to Markets***

This class of RM problems is the capacity management analog of the "allocation of resources to products" class. But, it takes advantage of an additional degree of freedom by considering how best to distribute the firm's resources across all of the markets that it serves. This is of course the problem that is solved in a free market by price signals; if the firm is able to generate its own internal price signals, then similarly desirable results can be obtained. (See Figure 4).

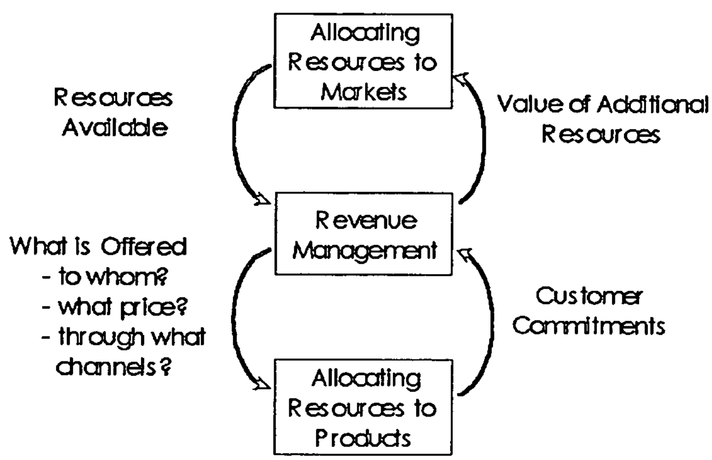


Figure 4

**Dynamic Re-allocation**

Dynamic re-allocation is an RM application that evaluates the opportunities that a firm has to move its resources from one market to another, based on expected demand. The model assumes that the total quantity and mix of resources is constant. This opportunity exists for firms that have mobile resources, such as passenger and cargo airlines and rental car companies. In the airline industry, the model is known as Demand-Driven Dispatch ($D^3$) and in the rental car industry it is known as Fleet Assignment. The model evaluates whether there are alternative, more valuable uses of resources, given that within a market the resources usage is already optimal.

The approach is to estimate the net revenue, or marginal value, of adding or reducing resources, on a unit by unit basis, in the potentially affected markets. The marginal values are obtained by optimizing the resource usage in all markets, over the model horizon. Since resources usually come in bundles (e.g., the number of seats on a 737-300, or the smallest number of car-days that can be transferred from one location to another), feasible adjustments are then evaluated. If the maximal net revenue difference associated with shifting one bundle of resources exceeds the out-of-pocket transfer cost, then that re-allocation is recommended. (See Figure 5).

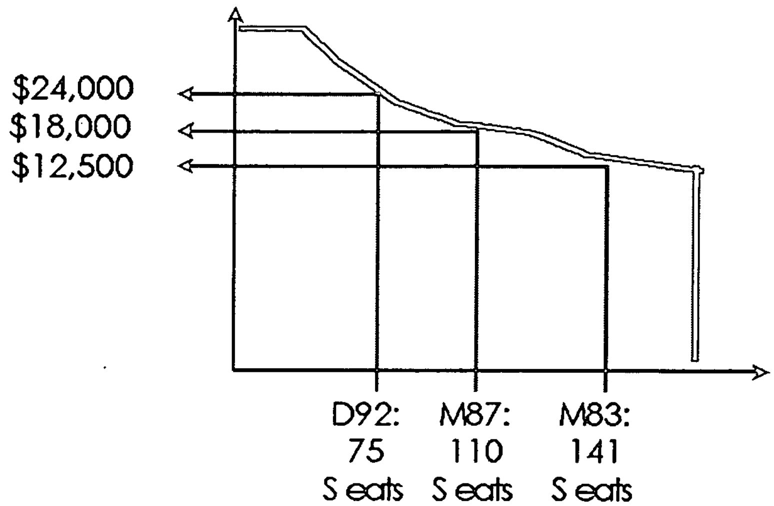


Figure 5

**Scheduling**

Scheduling, an even more complex problem of allocating resources to markets, is of great importance in the airline industry. In this problem, the products are itineraries that connect two cities. Demand for the products is estimated for city-pairs at different times of day, and day of week. Then, given the firm's infrastructure of hubs, its available fleet and their operational characteristics and the competitors' schedules, the optimal schedule is derived. The objective is to maximize expected revenues by choosing departure times, paths, and aircraft assignments that represent the schedule.

Solving this problem is costly, given its size, non-linearity and integrality. In practice, the entire problem is solved only periodically; then incremental revisions are evaluated between re-solves of the larger problem.

***Common Thread***

What ties these RM problems and applications together is their explicit, quantitative approach to the standard results and models of price theory. Simply stated, the job of RM is to support the profit-maximization decisions made in firms that typically have some degree of market power. These decisions include offering products and setting prices that capture as much consumer surplus as possible, and making short- and long-term production plans. However, unlike academic analysis and comparative statics, RM makes these models operational for the vast number of decisions that multi-product firms make every day.

**The Future of Revenue Management**

***Costs of computation***

We are all very aware of the dramatic declines in the cost of computation. We probably all have computers on our desks that have processors and disk drives many times faster, and much less expensive, than the computers that supported large corporate operations just a few years ago. The spreadsheet models that we run are vastly more intricate and voluminous than the "huge" mainframe planning models of the 1980s. As a consequence, an increasing number of corporate decision-making relies on information and computation. And because of this reliance, information technology is being described as a core competency of many more large corporations. Some have referred to this as Information Revolution, in contrast to the Industrial Revolution, which heralded the beginning of this century. One measure of this change is the recent announcement that Microsoft has overtaken General Electric as the number one company in the U.S. in market capitalization. Perhaps a herald of the next century!

These realities have made the recent growth in the RM discipline possible and its future growth nearly inevitable. Until recently, it was impractical for a large airline to solve a full network optimization problem. Flight legs were optimized independently, with some heuristic adjustments for network effects. Only in the last year or two has it been possible for a major airline to undertake to fully re-optimize the products it sells on its entire network, one a week. Within the next few years, we can imagine re-optimizations after every sale. An optimal placement tool implemented earlier this year for a television broadcaster would not have been possible without a supercomputer, as recently as three or four years ago.

***Electronic Commerce***

It is not an accident that RM had its origin in an industry whose sales and distribution channels were, even twenty years ago, dominated by electronic networks. The airline's global distribution systems (GDSs) and their messaging infrastructure made it possible for travel agents anywhere in the world to buy, on the spot market, seats on virtually any scheduled airline's flights, and receive immediate confirmation. They also make possible the vast storehouses of resource, product and customer information that is the grist for the RM models.

The rising importance of such sales and distribution channels throughout the economy is also a force that will compel the spread of RM tools. A result of this technological innovation is that buyers and sellers are getting closer. And it is more possible than ever to tailor product features to individual customer's tastes and preferences and to price products to individual customer's willingness to pay.

In a recent Business Week article entitled "Good-bye to Fixed Pricing" by Amy Cortese and Marcia Stepanek, they describe a new kind of Coke machine. A Coke machine that is hooked up to Coca Cola's computer network and that changes prices on the fly. Imagine the price of a cold drink that is proportional to the temperature; when it is 99 degrees in Atlanta, customers may be quite willing to pay an extra 20 cents for a cold Coke.

The ability to tailor and distribute products precisely, and the computational horsepower to make those precise decisions optimally, mean that RM tools are both important and feasible for many firms outside the travel industries where the discipline has matured. The significant, bottom-line successes that firms adopting it as a core competency have achieved, make will make the case compelling.

**Conclusion**

Currently, most of the $200 billion plus worldwide passenger airline revenue is controlled using Revenue Management tools. A significant fraction of the worldwide revenue from other travel industry firms (hotels, car and truck rental, cruise lines, passenger rail) is also managed using these tools. Firms in these industries, where RM is well established, routinely claim gains of from 3% to 8% of annual revenue.

Most major U.S. freight firms utilize some form of Revenue Management tools, as do some major television broadcasters. Estimates from early successes in these industries are comparable to that experience in the more mature industries.

By 2001, we expect annual spending on Revenue Management tools and services to exceed $300 million, as firms in these industries integrate the Revenue Management paradigm more fully, and firms in other industries, including telecommunications and retail trade, find ways to capture these revenue gains.

I'd like to close with quote from an article by Peter Bell, a professor of Management Science at University of Western Ontario, and president of International Federation of Operational Research Societies. The article was published in April 1998, in *OR/MS Today*, in response to a request from the editors for speculation about the practice of management science fifty years from now, in 2048.

"What will have caught the eye of every senior executive will be applications of operations research/management science on the revenue side of the firm. Revenue management concepts will be applied to almost everything that is sold, and will prove to be such a powerful competitive weapon that major firms will be living, and in many cases dying, according to RM algorithms. This will change the world; the supermarket or department store where product prices and advertising messages change every hour will, of necessity, be very different from the stores that we know today. The firms with the best Revenue Management will prosper and grow; the remainder will struggle to survive by restricting themselves to local or niche markets."

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